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## SENSOR A MULTIPLE SUBSTRATE SEMICONDUCTIVE SENSOR

### BACKGROUND OF THE INVENTION

A capacitive sensor for both absolute and relative pressure measurements is known from ~~the~~ German patent DE 33 10 643. ~~The~~ This capacitive sensor disclosed in this German patent ~~includes~~ has a first and second electrode, which are at a distance from one another and which form a measurement capacitance. The first electrode is disposed on a first substrate body and the second electrode on a second substrate body. These substrate bodies are laterally connected to one another, and the second substrate body in the region of the second electrode is constructed as a diaphragm ~~which that~~ can be deformed by pressure. The capacitive output signals of the sensor are conducted to an external evaluation unit and are evaluated there.

~~The~~ U.S. Patent 5,635,919 ~~discloses~~ a multipurpose sensor ~~which likewise is used to~~ measure distances, index of refraction, voltages, elongations, force, torque, temperature, pressure, magnetic and electric field strength, and other physical variables. This sensor ~~includes~~ has a signal source ~~this is,~~ affixed to a first substrate and provides, ~~to create~~ a modulated signal, ~~and~~ a receiver, ~~that~~ which is affixed on a second substrate at a fixed or variable distance to the signal source. ~~The sensor also includes,~~ an evaluation circuit with an amplifier to evaluate the signal, and a control unit to control the signal source. ~~The control computer~~ unit first calculates the signal delay, for which obviously some information regarding the transmitted signal must already be previously known and consequently stored and updated in the computer unit. From this, the desired physical quantity is determined.

~~For example, to~~ To measure the temperature, a gas at constant pressure is used as the transmission medium between the signal source and the receiver. The density of this gas ~~then~~ likewise changes with changing temperature.

A sensor with a different structure is described in the WO-A-97/42478. The sensor is integrated on a semiconductor and includes a light source as a signal source that provides light and a receiver as a signal detector, together with an evaluation and control unit. ~~are integrated on a semiconductor chip.~~ The light source or the receiver can be designed as a diaphragm, whose position is changed as function of ~~in dependence on the~~ pressure exerted on them.

U.S. Patent 5,689,107 discloses a different sensor for measuring force, acceleration, and pressure. The sensor includes ~~with~~ a light source and a plurality of spatially distributed receivers for the spatially resolved measurement of the distance of the arm and of the desired physical quantity in an evaluation unit, such as for example a force, an acceleration, or a pressure.:

U.S. Patent 4,478,076 discloses a throughflow sensor, in which thin-layer conductor tracks are used as heating elements or as several spatially distributed temperature sensors. An evaluation and control circuit is situated below these thin-layer elements.

A problem with these sensor devices is their relatively high power consumption.

Therefore, is a need for a relatively low power/efficient sensor device.

## SUMMARY OF THE INVENTION

Briefly, according to an aspect of the invention, a sensor includes a signal source that emits a physical signal, and a signal detector at a distance from the signal source to receive the physical signal. An evaluation unit is connected to the signal detector and evaluates the received physical signal to determine the relative distance between the signal source and the signal detector. The

signal source and the signal detector are situated on separate substrate bodies. A control unit is connected to the signal source, the signal detector, and the evaluation unit. The signal source, signal detector and the evaluation unit can each be individually turned on and off by the control unit.

~~Through the inventive measure, namely by means of t~~The control unit to operates the evaluation unit and supplementary thereto also the signal detector only for the time during which reception and evaluation of an emitted physical signal from the signal source is expected. As a result, the power consumption of the sensor is greatly reduced over a longer period of time, which again opens up a widened field of application in remote measurement stations, especially without connection to an electrical network.

The inventive sensor includes a signal source that emits a physical signal and a signal detector ~~which~~that is independent of the signal source and ~~which~~ is situated at a distance therefrom. The signal detector senses ~~receives the a~~ physical signal that ~~after the physical signal~~ has traversed the space between the signal source and the signal detector and has been effected by the characteristics of the space. The received physical signal ~~received by the signal detector~~ is conducted to an evaluation unit, which evaluates the received signal with the help of stored information about the signal source and thus about the emitted physical signal. The evaluation preferably includes a comparison of the expected signal, in terms of information about the signal source and thus about the emitted signal, with the actually received signal. Information is thus gained about the relative distance, that is a variable which is determined on the one hand by the spatial distance between the signal source and the signal detector and on the other hand also by the transmission properties of the region between the signal source and the signal detector. This relative distance thus must be distinguished from the purely geometrical distance of the signal source from the signal detector.

Through this type of interaction, if the geometric distance is known, information can be obtained about a change of the transmission behavior. From this, certain physical properties, such as density changes, temperature changes, or changes of the transport speed, or a change of the throughflow quantity or also their absolute values can be determined. On the other hand, if the transmission conditions are constant, information can be obtained about the change of the geometrical distance between the signal source and the signal detector. If the distance change is caused by an external force, a pressure, or an acceleration or the like, the change of these variables or their absolute values can be determined from this. Because the signal source and the signal detector are mutually independent and separate units, which ideally are not even connected electrically or electronically, it is possible to avoid mutual influences, ~~such as are known in connection with the capacitive sensor of the DE 33 10 643, where these mutual influences result from the two electrodes which form a measurement capacitance.~~

Among the large number of physical signals, radioactive signals, electromagnetic signals, optical signals, pressure variations, or thermal signals have proven to be especially suitable physical signals. By constructing the signal source and the signal detector on a common substrate or on two separate, closely spaced substrates, the sensor dimensions can be greatly reduced. This greatly extends the possible field of application of such a sensor, for example in the pharmaceutical industry or the chemical industry, where one deals with very high-grade or expensive substances with small volumes.

~~It has proven especially advantageous to keep t~~The distance between the signal source and the signal detector may be constant, especially by a self-enclosed, mechanically rigid structure of one or more substrates, and thereby make it possible to detect and evaluate changes in the transmission properties in the spatial region between the signal source and the signal detector. Such a sensor is

especially suited to measure changes in the gas density or in the transport speed or in the throughflow quantity or in the temperature distribution, or the absolute values thereof.

~~It also proves to be especially advantageous to keep t~~The transmission properties may be constant in the region between the signal source and the signal detector, and thereby make it possible to measure the distance between the signal source and the signal detector or its change. The transmission properties are ~~here kept~~ constant especially in that the space between the signal source and the signal detector has a uniform and permanent structure. Care must especially be taken to keep the temperature constant, to keep the composition constant, and to make the space isotropic, as well as similar variables. ~~It has proven especially advantageous to fill t~~The space may be filled completely with a noble gas or still better with a vacuum. In this case, by comparing the received signal with the information about the emitted signal, information can be obtained about the distance and its change.

A preferred embodiment of the invention comprises a control unit which is connected to the signal source and controls it. The control unit is also connected to the evaluation unit, thus updating the information about the signal source for the purpose of evaluating the received physical signals. Furthermore, the control unit may operate the evaluation unit and, as a supplement to this, also the signal detector only for the time during which reception and evaluation of an emitted physical signal by the signal source is expected. This design makes it possible to reduce ~~significantly~~ the electrical consumption of the sensor over an extended period of time, which again opens up a greater field of application, especially in remote measurement stations and especially without a connection to an electrical network.

The evaluation unit and/or the control unit preferably is disposed in the substrate body or bodies, especially in the region of the signal source or of the signal detector, thus achieving a higher

integration density of the sensor and smaller size. Furthermore, such an arrangement proves electronically advantageous, since short signal paths can be realized thereby and thus only minimal signal losses can occur, leading to an especially advantageous signal-to-noise ratio for the received physical signal. Furthermore, such an arrangement proves insensitive to external electronic noise influences, for example through the constantly present electromagnetic smog, which is especially important for application in the automotive field. Such a sensor, with an electronic evaluation unit and/or control unit integrated into the substrate body thus proves especially suitable for use in the automotive field. The control unit preferably is implemented in the substrate body separately from the evaluation unit. The control unit preferably is arranged in the region of the signal source, especially below this, while the evaluation unit is arranged in the substrate body in the region of the signal detector and especially below this. If the signal source and the signal detector are constructed separately on separate substrate bodies, this separation will also be realized for the control unit and the evaluation unit. This ~~most thoroughly~~ excludes mutual interference of the electronic units.

It has proven especially advantageous for the evaluation unit to have one or more signal-amplifying elements in the substrate body. By the arrangement in the substrate, especially below the signal detector, they can make an optimal contribution, since the short signal paths yields a very good signal-to-noise ratio and thus good resolution. This arrangement proves to be an especially suited design of the inventive sensor.

According to another embodiment of a sensor, in which the distance between the signal source and the signal detector is variable, the substrate body is designed as a diaphragm in the region of the signal receiver and/or the substrate body in the region of the signal detector. It changes its position due to an external force, an external pressure, or an acceleration of the sensor, and thereby changes the distance between the signal source and the signal detector. This allows a measurement

of the externally acting force, pressure or acceleration, or their changes. Thus, in a manner that is simple in its production engineering and that is sparing in its use of space, a universally suited sensor can be created for the measurement of forces, pressures, or accelerations, or the like.

Preferably, ~~a~~A sensor with a diaphragm has an additional damping device to damp undesirable vibrations, thus yielding measurement results of substantially better quality. That is, ~~since~~ interference with the measurement values by undesirable vibrations, especially due to resonances in the sensor (especially in the region of the diaphragm), can be excluded by such a damping device. For example, such damping devices can be formed by reinforcements in the region of the diaphragm, whereby the resonance frequencies of the diaphragm can be moved into specific, less troublesome regions, or its tendency to vibrate can be markedly reduced. Furthermore, it has proven advantageous to fill the closed volume of the sensor in the region of the diaphragm with a gas of higher density to achieve better damping. The region of the diaphragm may also be damped by a magnetic force, by disposing one or more magnets at suitable points around the diaphragm and equipping the diaphragm itself with an appropriate magnet. The magnetic interaction of these magnets causes the diaphragm to take up its equilibrium position faster and thus acts as a damping mechanism.

According to a preferred embodiment of the invention, the signal source and/or the signal detector are constructed in such a way that they are suited for space-resolving measurements. This can be done by the signal detector having spatially separated segments, which are activated by the physical signal in a spatially differentiated way, and which are evaluated in a spatially differentiated way by an appropriate electronic apparatus for the space-resolving processing of the received physical signals. This apparatus for space-resolving processing preferably is disposed within the substrate body, and especially below the signal detector in the region of the evaluation unit. This



leads to advantages comparable to those of the arrangement of the evaluation unit in the substrate body. This space-resolving measurement and evaluation makes it possible to obtain specific information about the type of excursion of the diaphragm, its mechanical condition, especially its fatigue state, and thus the possibility of healing the diaphragm and the sensor arrangement. This sensor therefore proves to be one which detects failure due to material fatigue of the diaphragm at an early stage and provides the user with the information that replacement of the inventive sensor is necessary.

A sensor in which the physical signal includes electromagnetic radiation has proven especially advantageous. Here, the signal source and/or the signal detector is realized by an antenna that includes conductor tracks on or in the substrate body. It is thus possible to create a complete sensor by an all-through production process of the substrate body, with the electrical conductor tracks implemented thereon or therein, and with electronic apparatuses, without additional, separate, other production processes, and without the additional attachment of separately produced signal sources or signal detectors. This sensor therefore proves economical and simple to produce, and reliable. This makes this sensor suitable for mass production, for example in the automotive field or also for use under extreme conditions, where there is an extraordinary need for quality.

The control unit of the sensor is preferably connected to the signal source and to the evaluation unit such that the current properties of the signal source are taken into account in the evaluation and thus in the comparison of the emitted physical signal and the expected physical signal with the actually received physical signals. If a change of the properties of the signal source results in a change of the emitted physical signal, for example by a diminished activity of a radioactive radiation source, this information is made available by the connecting line of the electronic arrangement to the evaluation device (also called evaluation unit), and is taken into account in the

evaluation. It is thus possible to take changes of the signal source into account automatically during the evaluation. This makes the measurement result of the sensor much more reliable.

## DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a first inventive embodiment of the sensor with a ~~radioactive~~ signal source and a ~~space-resolving~~ signal detector to measure ~~the throughflow~~ quantity;

FIG. 2 illustrates a second inventive embodiment of the sensor configured as a pressure sensor; and

FIG. 3 is a block diagram illustration of a sensor embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a sensor 100 for throughflow measurements. The sensor 100 includes a first substrate body 1; associated with a second substrate body 2 situated at a distance. ~~The A~~ signal source 3 is situated on the first substrate body 1 and faces the second substrate body 2. ~~The A~~ signal detector 4 is situated on the second substrate body 2 and faces the first substrate body 1. The signal source 3 and the signal detector 4 are separated by a spatial region 6. The signal detector is ~~It is~~ divided into four individual, spatially separated detector elements 4a, 4b, 4c, 4d. An electronic evaluation unit 5 is situated in the interior of the second substrate body 2, and receives sensed physical signals from the detector elements 4a-4d. The evaluation unit 5 ~~It is~~ connected to the individual signal detector elements 4a-4d, and ~~it~~ amplifies and evaluates the received sensed physical signals. This evaluation ~~also~~ comprises a differentiation with respect to the location of the individual signal detector elements, and thus an evaluation with respect to the spatial development of the

physical signal. This leads to a representation of the throughflow quantity through the spatial region 6 between the signal source 3 and the signal detector 4.

The signal source 3 shown in this embodiment is a thermal source. If the ~~intermediate space~~ spatial region 6 between the signal source 3 and the signal detector 4 is traversed by a slowly flowing fluid, the thermal energy is deflected only slightly in the flow direction; at a higher flow rate, it is deflected more strongly. Depending on the measure of deflection, various signal detector elements are excited, from which a conclusion can be drawn concerning the flow rate of ~~the substance A~~ A traversing the ~~spatial region~~ spatial region 6, and from this a measurement of the throughflow quantity can also be gained.

In this embodiment, the signal source 3 operates independently of the signal detector 4 and of the evaluation unit 5. Consequently, it is also not necessary to connect the signal detector 3 electrically to the signal detector 4 or to the evaluation unit 5. This is especially advantageous since it essentially excludes all problems associated with sealing electrical connections against the flowing measurement substance, and thus excludes the risk of malfunction or total failure of the sensor.

The construction of the sensor 100 with the two substrate bodies 1, 2 and the signal source 3 and signal detector 4, together with the integrated evaluation unit 5, situated thereon create an extremely small sensor structure. It can thus also be used in situations where, for example, only small amounts of substance are present, whose throughflow rate or throughflow quantity is to be measured. Such a throughflow quantity sensor proves to be especially suitable for the pharmaceutical industry or for test laboratories, prototype laboratories and analytical laboratories of the chemical industry.

FIG. 2 illustrates a pressure sensor 200 that includes a first substrate body 201 and a second substrate body 202. The sensor 200 also includes, ~~such that~~ a signal detector 204 that is situated on

the second substrate body 202, and an electronic evaluation unit 205 that is integrated into the second substrate body 202, ~~so as to~~ process the physical measurement signals sensed by the signal detector 204. Integrating the evaluation device 205 into the substrate body 202 directly at the signal detector 204 utilizes the available space for the entire sensor very efficiently. Furthermore, the signal paths from the signal detector 204 to the evaluation unit 205 are considerably shortened, resulting in an especially reliable evaluation of the measurement signals.

The first substrate body 201 is formed in such a way that it has a diaphragm which can be deformed by pressure. Usually the pressure is exerted on the membrane in the direction of the arrow.

A signal source 203 is situated in the area of the diaphragm, on that side which is associated with the signal detector 204. If the diaphragm is deformed through the action of an external pressure, the signal source 203 is thereby changed in its position, and this causes its distance from the signal detector 204 to change. If the physical signal emitted by the signal source 203 has a dependence on the distance it traverses before being received by the signal detector 204, information about the traversed path and thus about the distance between the signal source 203 and the signal detector 204 can be obtained from the evaluation of the received physical signal by the evaluation unit 205. Information thus can be obtained about the pressure exerted on the diaphragm. This information can relate both to the relative pressure and absolute pressure.

In one embodiment, the substrate bodies 201, 202 are made of silicon. This makes integration of the evaluation unit 205 especially simple. In addition, silicon has especially advantageous mechanical properties for the deformable diaphragm 205. The signal source 203 and the signal detector 204 are formed on their respective substrate bodies 201, 202, by conductor tracks with a specific shape and size so that on the one hand they act as a transmission antenna and on the other hand as a reception antenna for an appropriate electromagnetic signal. The electromagnetic

signal can be specified by the shape and size of the corresponding conductor tracks, so that the influences of interfering external electromagnetic fields can be reduced. As described before, the received electromagnetic signal depends on the transmission properties of the spatial region space 206 between the signal source 203 and the signal detector 204. If the space is filled by a homogeneous substance, which is non-specific in its electromagnetic transmission properties except for the transmission path, this design of the sensor proves to be especially suitable, for example, to measure the pressure on the diaphragm. If, in addition to the dependence of the transmission properties on the transmission path, there exists a dependence on temperature, this temperature dependence can be taken into account in the evaluation by the evaluation unit 205 through the use of a well-known thermometer. In such a case, however, this sensor inversely can also be used as a temperature sensor, if the distance between the signal source 3 and the signal detector 4 is held constant or can be determined in another way.

FIG. 3 is a block diagram illustration of a sensor embodiment 300. The sensor 300 includes the transmission source 303, which is separated from the signal detector 304 by the spatial region 306. The signal source 303 transmits a physical signal in the direction of the signal detector 304. This signal is indicated by the arrow B and traverses the spatial region 306. The sensor has a control unit 307, which is connected to the transmission source 303 by a control line, and actuates ~~the said~~ transmission source to emit a certain physical signal at a specific time. Furthermore, the control unit 307, which preferably is integrated in the substrate body 1 close to the signal source 303, is connected to the signal detector 304. The evaluation unit ~~4~~ 305 is integrated into the second substrate body 302, which is associated with the signal detector 304. ~~By means of~~ The connecting lines to the signal detector 304 and to the evaluation unit 305, ~~these are switched on by the control unit 307 based upon specifically in knowledge of the control data of the signal source and the expected~~

reception time of the physical signal. This ensures that the signal detector 304 detects the physical signal emitted by the signal source 303 and that the evaluation unit 305 ~~will~~ makes an appropriate evaluation. Outside this time window, necessary for reliable operation, the signal detector 304 or also the evaluation unit 305 is turned off, thus significantly reducing the energy consumption of the sensor over time. The like also holds for the signal source 303.

The evaluation unit 305 is connected to the control unit 307 and the signal detector 304, and ~~the evaluation unit 305 received the~~ through which connection the received physical signal from the ~~signal detector 304 is conducted to the evaluation unit 5.~~ The evaluation unit 305 is also connected ~~to~~ However, it is also connected to an external display 308. The measurement variables measured by the evaluation unit 305, such as pressure, force, acceleration, throughflow rate, throughflow quantity, temperature, or the like, are displayed to the user on this display unit.

What is claimed is:

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## **A MULTIPLE SUBSTRATE SEMICONDUCTIVE SENSOR**

### **BACKGROUND OF THE INVENTION**

A capacitive sensor for both absolute and relative pressure measurements is known from German patent DE 33 10 643. The capacitive sensor disclosed in this German patent includes a first and second electrode, which are at a distance from one another and which form a measurement capacitance. The first electrode is disposed on a first substrate body and the second electrode on a second substrate body. These substrate bodies are laterally connected to one another, and the second substrate body in the region of the second electrode is constructed as a diaphragm that can be deformed by pressure. The capacitive output signals of the sensor are conducted to an external evaluation unit and are evaluated there.

U.S. Patent 5,635,919 discloses a multipurpose sensor used to measure distance, index of refraction, voltage, elongation, force, torque, temperature, pressure, magnetic and electric field strength, and other physical variables. This sensor includes a signal source this is affixed to a first substrate and provides a modulated signal, and a receiver that is affixed on a second substrate at a fixed or variable distance to the signal source. The sensor also includes an evaluation circuit with an amplifier to evaluate the signal, and a control unit to control the signal source. The control unit first calculates the signal delay, for which obviously some information regarding the transmitted signal must already be previously known and consequently stored and updated in the computer unit. From this the desired physical quantity is determined.

To measure the temperature, a gas at constant pressure is used as the transmission medium between the signal source and the receiver. The density of this gas changes with changing temperature.



A sensor with a different structure is described in the WO-A-97/42478. The sensor is integrated on a semiconductor and includes signal source that provides light and a receiver as a signal detector, together with an evaluation and control unit. The light source or the receiver can be designed as a diaphragm, whose position is changed as function of pressure exerted on them.

U.S. Patent 5,689,107 discloses a different sensor for measuring force, acceleration and pressure. The sensor includes a light source and a plurality of spatially distributed receivers for the spatially resolved measurement of the distance of the arm and of the desired physical quantity in an evaluation unit, such as for example a force, an acceleration, or a pressure.

U.S. Patent 4,478,076 discloses a throughflow sensor, in which thin-layer conductor tracks are used as heating elements or as several spatially distributed temperature sensors. An evaluation and control circuit is situated below these thin-layer elements.

A problem with these sensor devices is their relatively high power consumption.

Therefore, is a need for a relatively low power/efficient sensor device.

## **SUMMARY OF THE INVENTION**

Briefly, according to an aspect of the invention, a sensor includes a signal source that emits a physical signal, and a signal detector at a distance from the signal source to receive the physical signal. An evaluation unit is connected to the signal detector and evaluates the received physical signal to determine the relative distance between the signal source and the signal detector. The signal source and the signal detector are situated on separate substrate bodies. A control unit is connected to the signal source, the signal detector, and the evaluation unit. The signal source, signal detector and the evaluation unit can each be individually turned on and off by the control unit.

The control unit operates the evaluation unit and supplementary thereto also the signal detector only for the time during which reception and evaluation of an emitted physical signal from the signal source is expected. As a result, the power consumption of the sensor is greatly reduced over a longer period of time, which again opens up a widened field of application in remote measurement stations, especially without connection to an electrical network.

The inventive sensor includes a signal source that emits a physical signal and a signal detector that is independent of the signal source and is situated at a distance therefrom. The signal detector senses a physical signal that has traversed the space between the signal source and the signal detector and has been effected by the characteristics of the space. The received physical signal is conducted to an evaluation unit, which evaluates the received signal with the help of stored information about the signal source and thus about the emitted physical signal. The evaluation preferably includes a comparison of the expected signal, in terms of information about the signal source and thus about the emitted signal, with the actually received signal. Information is thus gained about the relative distance, that is a variable which is determined on the one hand by the spatial distance between the signal source and the signal detector and on the other hand also by the transmission properties of the region between the signal source and the signal detector. This relative distance thus must be distinguished from the purely geometrical distance of the signal source from the signal detector.

Through this type of interaction, if the geometric distance is known, information can be obtained about a change of the transmission behavior. From this, certain physical properties, such as density changes, temperature changes, or changes of the transport speed, or a change of the throughflow quantity or also their absolute values can be determined. On the other hand, if the transmission conditions are constant, information can be obtained about the change of the

geometrical distance between the signal source and the signal detector. If the distance change is caused by an external force, a pressure, or an acceleration or the like, the change of these variables or their absolute values can be determined from this. Because the signal source and the signal detector are mutually independent and separate units, which ideally are not even connected electrically or electronically, it is possible to avoid mutual influences.

Among the large number of physical signals, radioactive signals, electromagnetic signals, optical signals, pressure variations, or thermal signals have proven to be especially suitable physical signals. By constructing the signal source and the signal detector on a common substrate or on two separate, closely spaced substrates, the sensor dimensions can be greatly reduced. This greatly extends the possible field of application of such a sensor, for example in the pharmaceutical industry or the chemical industry, where one deals with very high-grade or expensive substances with small volumes.

The distance between the signal source and the signal detector may be constant, especially by a self-enclosed, mechanically rigid structure of one or more substrates, and thereby make it possible to detect and evaluate changes in the transmission properties in the spatial region between the signal source and the signal detector. Such a sensor is especially suited to measure changes in the gas density or in the transport speed or in the throughflow quantity or in the temperature distribution, or the absolute values thereof.

The transmission properties may be constant in the region between the signal source and the signal detector, and thereby make it possible to measure the distance between the signal source and the signal detector or its change. The transmission properties are kept constant especially in that the space between the signal source and the signal detector has a uniform and permanent structure. Care must especially be taken to keep the temperature constant, to keep the composition constant, and to

make the space isotropic, as well as similar variables. The space may be filled completely with a noble gas or still better with a vacuum. In this case, by comparing the received signal with the information about the emitted signal, information can be obtained about the distance and its change.

A preferred embodiment of the invention comprises a control unit which is connected to the signal source and controls it. The control unit is also connected to the evaluation unit, thus updating the information about the signal source for the purpose of evaluating the received physical signals. Furthermore, the control unit may operate the evaluation unit and, as a supplement to this, also the signal detector only for the time during which reception and evaluation of an emitted physical signal by the signal source is expected. This design makes it possible to reduce the electrical consumption of the sensor over an extended period of time, which again opens up a greater field of application, especially in remote measurement stations and especially without a connection to an electrical network.

The evaluation unit and/or the control unit preferably is disposed in the substrate body or bodies, especially in the region of the signal source or of the signal detector, thus achieving a higher integration density of the sensor and smaller size. Furthermore, such an arrangement proves electronically advantageous, since short signal paths can be realized thereby and thus only minimal signal losses can occur, leading to an especially advantageous signal-to-noise ratio for the received physical signal. Furthermore, such an arrangement proves insensitive to external electronic noise influences, for example through the constantly present electromagnetic smog, which is especially important for application in the automotive field. Such a sensor, with an electronic evaluation unit and/or control unit integrated into the substrate body thus proves especially suitable for use in the automotive field. The control unit preferably is implemented in the substrate body separately from the evaluation unit. The control unit preferably is arranged in the region of the signal source,

especially below this, while the evaluation unit is arranged in the substrate body in the region of the signal detector and especially below this. If the signal source and the signal detector are constructed separately on separate substrate bodies, this separation will also be realized for the control unit and the evaluation unit. This excludes mutual interference of the electronic units.

It has proven especially advantageous for the evaluation unit to have one or more signal-amplifying elements in the substrate body. By the arrangement in the substrate, especially below the signal detector, they can make an optimal contribution, since the short signal paths yields a very good signal-to-noise ratio and thus good resolution. This arrangement proves to be an especially suited design of the inventive sensor.

According to another embodiment of a sensor, in which the distance between the signal source and the signal detector is variable, the substrate body is designed as a diaphragm in the region of the signal receiver and/or the substrate body in the region of the signal detector. It changes its position due to an external force, an external pressure, or an acceleration of the sensor, and thereby changes the distance between the signal source and the signal detector. This allows a measurement of the externally acting force, pressure or acceleration, or their changes. Thus, in a manner that is simple in its production engineering and that is sparing in its use of space, a universally suited sensor can be created for the measurement of forces, pressures, or accelerations, or the like.

A sensor with a diaphragm has an additional damping device to damp undesirable vibrations, thus yielding measurement results of substantially better quality. That is, interference with the measurement values by undesirable vibrations, especially due to resonances in the sensor (especially in the region of the diaphragm), can be excluded by such a damping device. For example, such damping devices can be formed by reinforcements in the region of the diaphragm, whereby the resonance frequencies of the diaphragm can be moved into specific, less troublesome regions, or its

tendency to vibrate can be markedly reduced. Furthermore, it has proven advantageous to fill the closed volume of the sensor in the region of the diaphragm with a gas of higher density to achieve better damping. The region of the diaphragm may also be damped by a magnetic force, by disposing one or more magnets at suitable points around the diaphragm and equipping the diaphragm itself with an appropriate magnet. The magnetic interaction of these magnets causes the diaphragm to take up its equilibrium position faster and thus acts as a damping mechanism.

According to a preferred embodiment of the invention, the signal source and/or the signal detector are constructed in such a way that they are suited for space-resolving measurements. This can be done by the signal detector having spatially separated segments, which are activated by the physical signal in a spatially differentiated way, and which are evaluated in a spatially differentiated way by an appropriate electronic apparatus for the space-resolving processing of the received physical signals. This apparatus for space-resolving processing preferably is disposed within the substrate body, and especially below the signal detector in the region of the evaluation unit. This leads to advantages comparable to those of the arrangement of the evaluation unit in the substrate body. This space-resolving measurement and evaluation makes it possible to obtain specific information about the type of excursion of the diaphragm, its mechanical condition, especially its fatigue state, and thus the possibility of healing the diaphragm and the sensor arrangement. This sensor therefore proves to be one which detects failure due to material fatigue of the diaphragm at an early stage and provides the user with the information that replacement of the inventive sensor is necessary.

A sensor in which the physical signal includes electromagnetic radiation has proven especially advantageous. Here, the signal source and/or the signal detector is realized by an antenna that includes conductor tracks on or in the substrate body. It is thus possible to create a complete

sensor by an all-through production process of the substrate body, with the electrical conductor tracks implemented thereon or therein, and with electronic apparatuses, without additional, separate, other production processes, and without the additional attachment of separately produced signal sources or signal detectors. This sensor therefore proves economical and simple to produce, and reliable. This makes this sensor suitable for mass production, for example in the automotive field or also for use under extreme conditions, where there is an extraordinary need for quality.

The control unit of the sensor is preferably connected to the signal source and to the evaluation unit such that the current properties of the signal source are taken into account in the evaluation and thus in the comparison of the emitted physical signal and the expected physical signal with the actually received physical signals. If a change of the properties of the signal source results in a change of the emitted physical signal, for example by a diminished activity of a radioactive radiation source, this information is made available by the connecting line of the electronic arrangement to the evaluation device (also called evaluation unit), and is taken into account in the evaluation. It is thus possible to take changes of the signal source into account automatically during the evaluation. This makes the measurement result of the sensor much more reliable.

## **DETAILED DESCRIPTION OF THE DRAWINGS**

FIG. 1 illustrates a first inventive embodiment of the sensor with a signal source and a signal detector to measure flow quantity;

FIG. 2 illustrates a second inventive embodiment of the sensor configured as a pressure sensor; and

FIG. 3 is a block diagram illustration of a sensor embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a sensor 100 for throughflow measurements. The sensor 100 includes a first substrate body 1 associated with a second substrate body 2 situated at a distance. A signal source 3 is situated on the first substrate body 1 and faces the second substrate body 2. A signal detector 4 is situated on the second substrate body 2 and faces the first substrate body 1. The signal source 3 and the signal detector 4 are separated by a spatial region 6. The signal detector is divided into four individual, spatially separated detector elements 4a, 4b, 4c, 4d. An electronic evaluation unit 5 is situated in the interior of the second substrate body 2, and receives sensed physical signals from the detector elements 4a-4d. The evaluation unit 5 is connected to the individual signal detector elements 4a-4d, and amplifies and evaluates the received sensed physical signals. This evaluation comprises a differentiation with respect to the location of the individual signal detector elements, and thus an evaluation with respect to the spatial development of the physical signal. This leads to a representation of the throughflow quantity through the spatial region 6 between the signal source 3 and the signal detector 4.

The signal source 3 shown in this embodiment is a thermal source. If the spatial region 6 between the signal source 3 and the signal detector 4 is traversed by a slowly flowing fluid, the thermal energy is deflected only slightly in the flow direction; at a higher flow rate, it is deflected more strongly. Depending on the measure of deflection, various signal detector elements are excited, from which a conclusion can be drawn concerning the flow rate of substance A traversing the spatial region 6, and from this a measurement of the throughflow quantity can also be gained.

In this embodiment, the signal source 3 operates independently of the signal detector 4 and of the evaluation unit 5. Consequently, it is also not necessary to connect the signal detector 3 electrically to the signal detector 4 or to the evaluation unit 5. This is especially advantageous since



it essentially excludes all problems associated with sealing electrical connections against the flowing measurement substance, and thus excludes the risk of malfunction or total failure of the sensor.

The construction of the sensor 100 with the two substrate bodies 1, 2 and the signal source 3 and signal detector 4, together with the integrated evaluation unit 5, situated thereon create an extremely small sensor structure. It can thus also be used in situations where, for example, only small amounts of substance are present, whose throughflow rate or throughflow quantity is to be measured. Such a throughflow quantity sensor proves to be especially suitable for the pharmaceutical industry or for test laboratories, prototype laboratories and analytical laboratories of the chemical industry.

FIG. 2 illustrates a pressure sensor 200 that includes a first substrate body 201 and a second substrate body 202. The sensor 200 also includes a signal detector 204 that is situated on the second substrate body 202, and an electronic evaluation unit 205 that is integrated into the second substrate body 202, process the physical measurement signals sensed by the signal detector 204. Integrating the evaluation device 205 into the substrate body 202 directly at the signal detector 204 utilizes the available space for the entire sensor very efficiently. Furthermore, the signal paths from the signal detector 204 to the evaluation unit 205 are considerably shortened, resulting in an especially reliable evaluation of the measurement signals.

The first substrate body 201 is formed in such a way that it has a diaphragm which can be deformed by pressure. Usually the pressure is exerted on the membrane in the direction of the arrow. A signal source 203 is situated in the area of the diaphragm, on that side which is associated with the signal detector 204. If the diaphragm is deformed through the action of an external pressure, the signal source 203 is thereby changed in its position, and this causes its distance from the signal detector 204 to change. If the physical signal emitted by the signal source 203 has a dependence on

the distance it traverses before being received by the signal detector 204, information about the traversed path and thus about the distance between the signal source 203 and the signal detector 204 can be obtained from the evaluation of the received physical signal by the evaluation unit 205. Information thus can be obtained about the pressure exerted on the diaphragm. This information can relate both to the relative pressure and absolute pressure.

In one embodiment, the substrate bodies 201, 202 are made of silicon. This makes integration of the evaluation unit 205 especially simple. In addition, silicon has especially advantageous mechanical properties for the deformable diaphragm 205. The signal source 203 and the signal detector 204 are formed on their respective substrate bodies 201, 202, by conductor tracks with a specific shape and size so that on the one hand they act as a transmission antenna and on the other hand as a reception antenna for an appropriate electromagnetic signal. The electromagnetic signal can be specified by the shape and size of the corresponding conductor tracks, so that the influences of interfering external electromagnetic fields can be reduced. As described before, the received electromagnetic signal depends on the transmission properties of the spatial region 206 between the signal source 203 and the signal detector 204. If the space is filled by a homogeneous substance, which is non-specific in its electromagnetic transmission properties except for the transmission path, this design of the sensor proves to be especially suitable, for example, to measure the pressure on the diaphragm. If, in addition to the dependence of the transmission properties on the transmission path, there exists a dependence on temperature, this temperature dependence can be taken into account in the evaluation by the evaluation unit 205 through the use of a well-known thermometer. In such a case, however, this sensor inversely can also be used as a temperature sensor, if the distance between the signal source 3 and the signal detector 4 is held constant or can be determined in another way.

FIG. 3 is a block diagram illustration of a sensor embodiment 300. The sensor 300 includes the transmission source 303, which is separated from the signal detector 304 by the spatial region 306. The signal source 303 transmits a physical signal in the direction of the signal detector 304. This signal is indicated by the arrow B and traverses the spatial region 306. The sensor has a control unit 307, which is connected to the transmission source 303 by a control line, and actuates the transmission source to emit a certain physical signal at a specific time. Furthermore, the control unit 307, which preferably is integrated in the substrate body 1 close to the signal source 303, is connected to the signal detector 304. The evaluation unit 305 is integrated into the second substrate body 302, which is associated with the signal detector 304. The connecting lines to the signal detector 304 and to the evaluation unit 305 are switched on by the control unit 307 based upon control data of the signal source and the expected reception time of the physical signal. This ensures that the signal detector 304 detects the physical signal emitted by the signal source 303 and that the evaluation unit 305 makes an appropriate evaluation. Outside this time window, necessary for reliable operation, the signal detector 304 or also the evaluation unit 305 is turned off, thus significantly reducing the energy consumption of the sensor over time. The like also holds for the signal source 303.

The evaluation unit 305 is connected to the control unit 307 and the signal detector 304, and the evaluation unit 305 receives the received physical signal from the signal detector 304. The evaluation unit 305 is also connected to an external display 308. The measurement variables measured by the evaluation unit 305, such as pressure, force, acceleration, throughflow rate, throughflow quantity, temperature, or the like, are displayed to the user on this display unit.

What is claimed is: